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Air flow through cloth screening

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AIR FLOW THROUGH

CLOTH SCREENING

BY

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A

THESIS

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Professor of Mechanical Engineering

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Special thanks is also due to Mr. Norman Wolk, for I have used the same apparatus which he had set up for his tests on air flow through metallic screening.

I would also want to thank Professor R. H. Young for the assistance he rendered me in the mechanical laboratory.

Acknowledgement is also given both to Philip Quatrochi and Moris Bolay for their assistance in making the test runs.

PREFACE

The selection of the problem for which this paper offers a solution was made from a list of theses subjects submitted by the U. S. Air Force. The problem called for the development of a method or formula where the air flow through woven materials, such as metallic screening and woven cloth, could be obtained in terms of the pressure drop across the material. The range of pressure differentials to be investigated was from zero to twenty inches of water.

In this paper the work is confined to woven cloth such as nylon, rayon and cotton fabrics. A former graduate of our school, Mr. N. B. Wolk, has worked on metallic screenings.

The fabrics used in the experimental portion of the work have been obtained locally.

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INTRODUCTION

The object of this investigation is to obtain an expression whereby flow of air through woven cloth can be predicted with a reasonable degree of accuracy, in terms of the pressure drop across the screen, the density, the viscosity of the air flowing; these latter properties being functions of the pressure and temperature of the air.

The development of an expression from which to predict the relationship between the air flow through a screen and the pressure drop across it without resort to experimental procedure seems to the author to be worthwhile undertaking.

The chief aim of this investigation was to obtain an expression for air flow in terms of the pressure drop across the screen. Air has been used as the working medium when the experiments were conducted. But it could be applied to most compressible fluids, which makes the mathematical expression reasonably general.

REVIEW OF LITERATURE

So far as the author was able to ascertain from the literature available locally, no work had been done previously paralleling that covered by this thesis except for a thesis written by Mr. Norman Wolk, a former graduate of the School of Mines and Metallurgy, on air flow through metallic screening.

TABLE I

LIST OF SYMBOLS

Symbol	Quantity	Units
ρ	Density	slugs/cu.ft.
μ	Viscosity	lb.sec./sq.ft.
Q	Air flow/sq. ft. of screen	ft./sec.
P	Screen pressure drop	lb./sq.ft.
M	Mesh	1/ft.
D	Thread diameter	ft.
H	Orifice pressure drop	Scale units of manometer oil
h	Screen pressure drop	inches of H_2O

TABLE II

Variable	Symbol	Dim. Formula	Exponents of		
			Time	Length	Mass
Air flow/sq.ft. of screen	Q	L/T	-1	+1	
Density of air	ρ	M/L^3		-3	1
Pressure drop through screen	P	M/LT^2	-2	-1	1
Viscosity	μ	M/LT	-1	-1	1
Thread Dim.	D	L		1	
Mesh	M	1/L		-1	

(1) P. W. Bridgman, Dimensional Analysis, New Haven, Yale University Press, 1922, p. 110.

DISCUSSION

In order to develop the general form of the equation for air flow through fabric screenings, the author sees fit to resort to dimensional analysis. This consists of selecting those variables upon which another variable quantity depends.

<u>The Application of Dimensional Analysis to the Problem of Air Flow Through Fabric Screenings</u>.

The variables upon which the air flow depends are the density of air, the viscosity of air, the pressure drop across the screen, the thread thickness of the screen, and the mesh. One other variable such as the velocity of air was assumed to be involved in the problem; but it was found to have no relation with the problem in hand, since its exponent gave a value of zero, and consequently made it drop out of the dimensional equation.

Setting up an expression for the flow (Q) in terms of the other variables

$$Q = K\rho^a P^b \mu^c D^d M^e \qquad (a)$$

where K is the constant of proportionality.

Substituting the dimensional formulas from Table II into eq. (a)

$$LT^{-1} = K(M^aL^{-3a})(M^bL^{-b}T^{2b})(M^cL^{-c}T^{-c})(L^d)(L^{-e}) \qquad (b)$$

Now writing the summation equation

$$\Sigma L \quad 1 = -3a - b - c + d - e \qquad (c)$$

$$\Sigma T \quad -1 = -2b - c \qquad (d)$$

$$\Sigma M \quad 0 = a + b + c \qquad (e)$$

Solving for (c) from eq. d

$$c = 1 - 2b$$

Substituting this value of (c) into eq. e

$$0 = a + b + 1 - 2b$$

$$0 = a + 1 - b \quad \text{or} \quad a = b - 1$$

Substituting the values for (a) and (c) into eq. (c)

$$1 = -3b + 3 - b - 1 + 2b + d - e$$
$$1 = d - e - 2b + 2$$
$$e = 1 - 2b + d$$

Now we have reduced all of the exponents in terms of (b) and (d) which is as far as the original equation can be reduced using dimensional analysis.

Substituting the values for exponents (a), (c) and (e) into eq. (a) we get,

$$Q = K(\rho^{b-1})(P^{b})(\mu^{1-2b})(D^{d})(M^{1-2b+d}) \qquad (f)$$

Collecting terms of like exponents

$$Q = K\left(\frac{\rho P}{\mu^2 M^2}\right)^{b}(DM)^{d}\left(\frac{\mu M}{\rho}\right) \qquad (g)$$

The above equation is one of the general forms of the expression for air flow through screens, in which all of the quantities in the parenthesis are measurable.

The problem is now to determine the value of these 3 constants experimentally, namely K, b, and d; which can be done by setting up the apparatus and running tests on different fabric samples. The specimens used were nylon parachute cloth, rayon, a sample from silk stockings, cotton and a different cotton sample. Out of five different samples, I have been able to use only three of them; namely, rayon, nylon and cotton. The mesh of the silk sample was very loosely woven and the air supply was not enough to run through the fabric. On the other hand the mesh of the cotton sample No. 2 was very tightly woven and for a given pressure drop namely, 1-20 inches of water across the fabric, no appreciable pressure drop could be read on the orifice meter manometer which registers the flow of air.

The data which follows is a tabulation of pressure drop across the orifice meter versus pressure drop across the screen. The reading for the orifice drop (H) is in scale units of manometer oil. Each of these scale units measured 0.0735 inches. This constant was used later to convert the orifice drop to inches of water. As will be shown later in the discussion the air flow through the orifice is proportional to the square root of the pressure drop (H), and therefore for convenience sake the following data plots ($\sqrt{H}$) where (H) is in units of manometer oil, against the screen pressure drop (h) in inches of water. The resulting curves will be of the same form as a plot of the air flow Q versus screen drop (h), the difference being the constant of proportionality between (Q) and (H).

DESCRIPTION OF PROCEDURE FOLLOWED FOR THE EXPERIMENTAL DETERMINATION OF K, (b) and (d)

As was mentioned in the acknowledgement, the apparatus used by the author in conducting the experiment was built by a former graduate, Norman Wolk.

The supply of air was obtained from a compressed air main line running beneath the Mechanical Engineering Laboratory, which was fed by a compressor in the Missouri School of Mines Power Plant.

The capacity of this compressor was 230 cu.ft./min. and the pressure in the line between 80 psi to 100 psi.

Arrangements were made to conduct the tests during times when there was no other load on the system, which made it possible for me to use the entire output of the compressor.

This source of air proved adequate in all but one respect, this being the relatively high moisture content of the air, which resulted from the absence of an after cooler in the system. The moisture in the air tended to clog the very small openings in these fine fabrics. But by using screens of a mesh around 80 threads/inch, the effect of the moisture became negligible.

A drawing of the apparatus with complete notation is shown in Fig. (1).

A Meriam Manometer (A) which read in inches of water was used to measure the pressure drop across the screens.

Red manometer oil of specific gravity 0.834 was used in the orifice meter (B).

The screen samples were made up as shown in Fig. (2) inserted between flanges (C) and secured by flange bolts. A gate valve (D) was inserted in the air supply pipeline upstream from the orifice meter to blow off any condensate which may have collected in the line prior to the test. A globe valve (E) was used to regulate the quantity of air flowing, and a thermometer (F) was inserted upstream from the orifice meter to measure the air temperature.

TABLE III

Screen	Thread Thickness in inches	Mesh threads/inch
(A) Nylon	0.0083	95
(B) Rayon	0.0071	91
(C) Cotton	0.0074	90

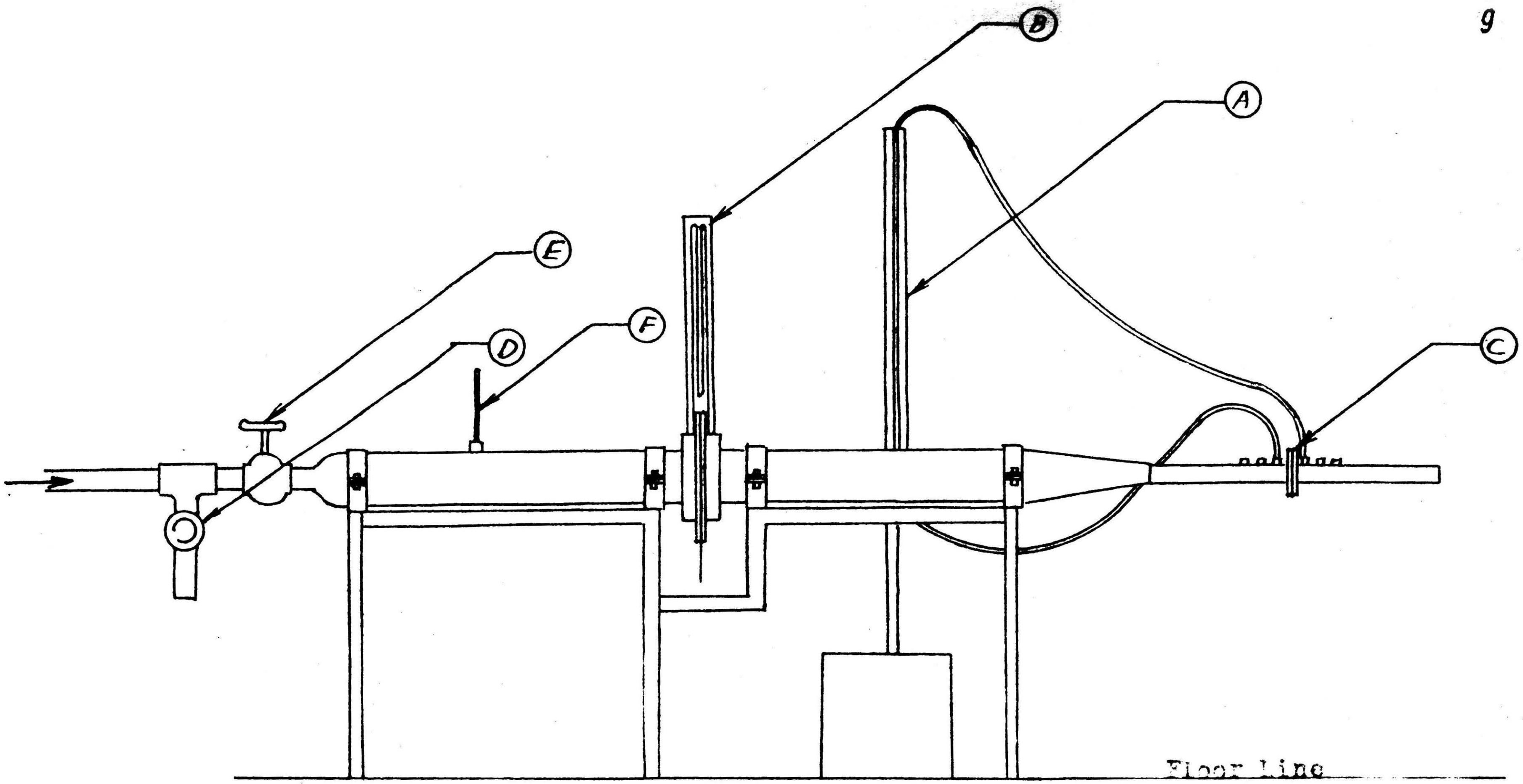


Fig. 1

APPARATUS FOR EXPERIMENTAL
DETERMINATION OF AIR FLOW

A - Water Manometer
B - Orifice Meter
C - Flanges
D - Gate Valve
E - Globe Valve
F - Thermometer

PROCEDURE FOR MEASURING THE MESH AND THE THREAD THICKNESSES OF THE FABRICS

The mesh and the thread thicknesses of the samples were measured making use of an eye piece measuring microscope.

The mesh and thread thicknesses of every sample were measured four different times and averages were taken. The surface condition of the nylon and rayon threads looked very similar, but the surface condition of the cotton fabric was altogether different from nylon and rayon samples. It could be expressed as fuzzy.

A TYPICAL SCREEN SAMPLE

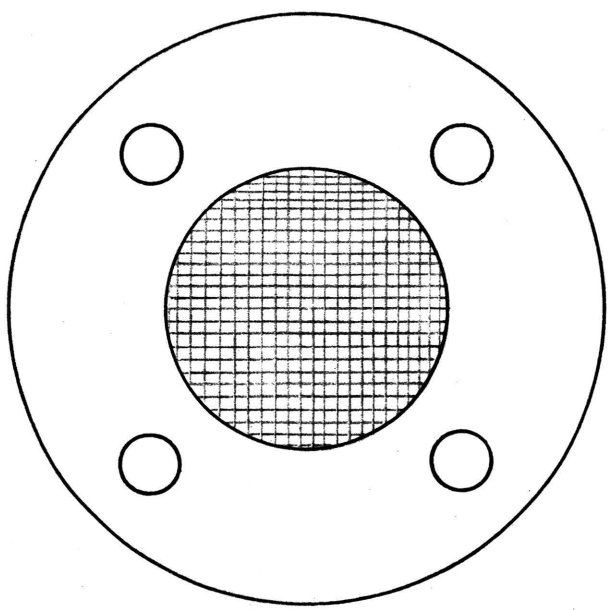


FIG. I

TABLE IV

Screen (A) Nylon. Temp: 82°F

Run	Orifice Pressure Drop (H) in Units of Manometer Oil	$\sqrt{H}$	Screen Pressure Drop (h) Inches of Water
a	0.25	0.5	3.0
b	0.50	0.707	6.0
c	0.85	0.922	10.4
d	1.2	1.1	15.0
e	1.7	1.3	21
f	2.0	1.41	25

TABLE V

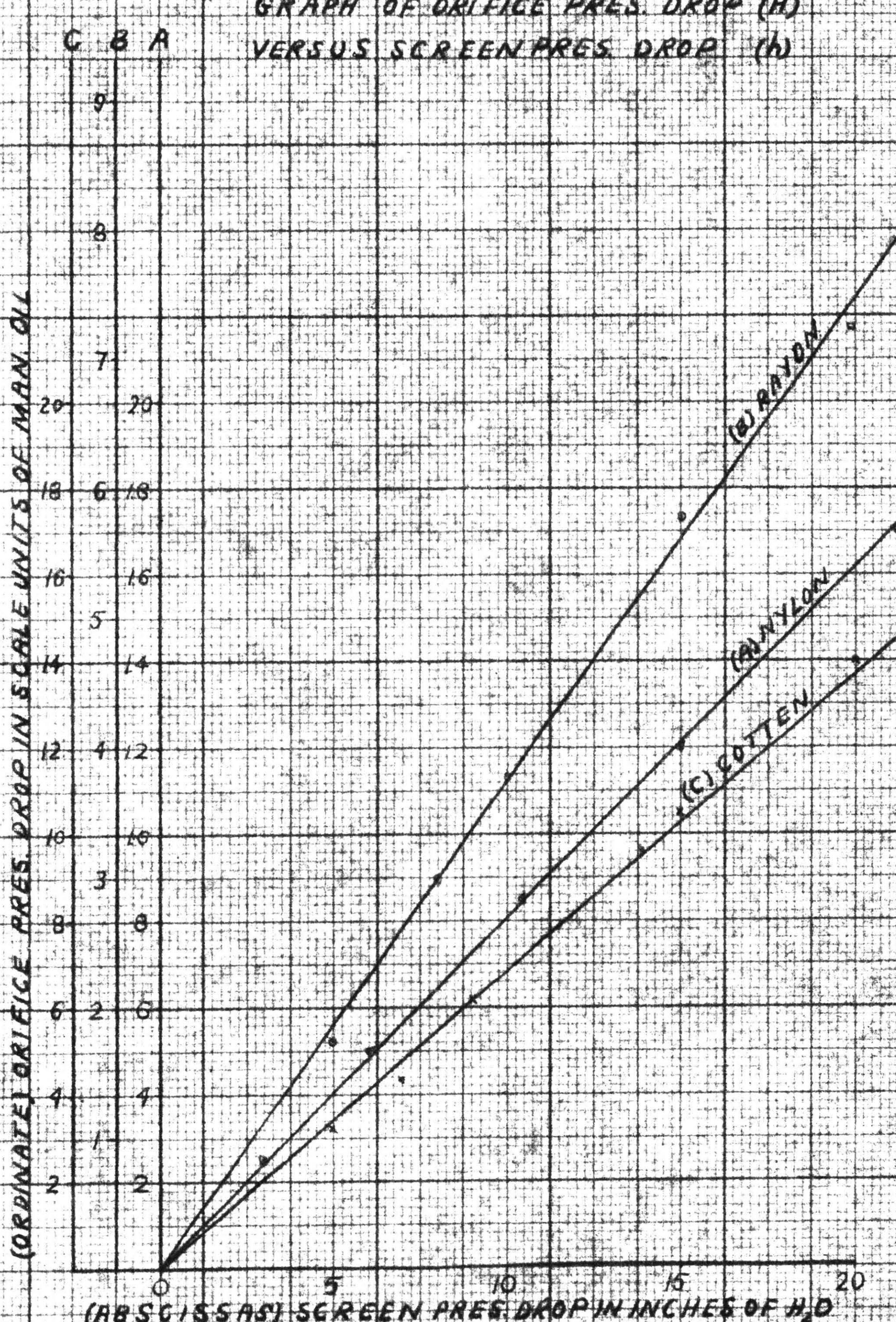
Screen (B) Rayon Temp: 82°F

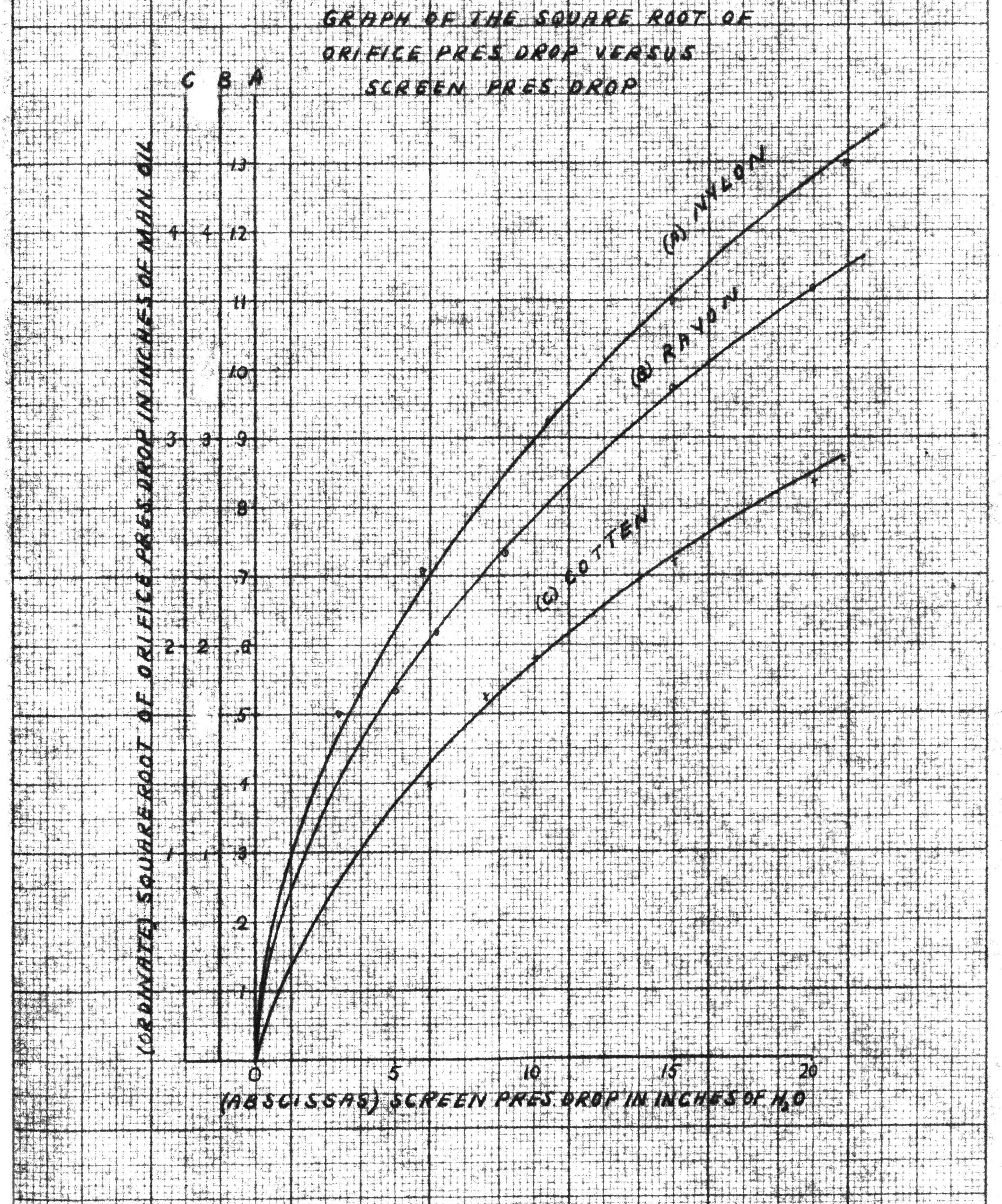
Run	Orifice Pressure Drop (H) in Units of Manometer Oil	$\sqrt{H}$	Screen Pressure Drop (h) Inches of Water
a	1.75	1.32	5
b	3.0	1.73	8
c	3.75	1.94	10
d	5.8	2.41	15
e	7.8	2.79	20
f	9.8	3.13	25

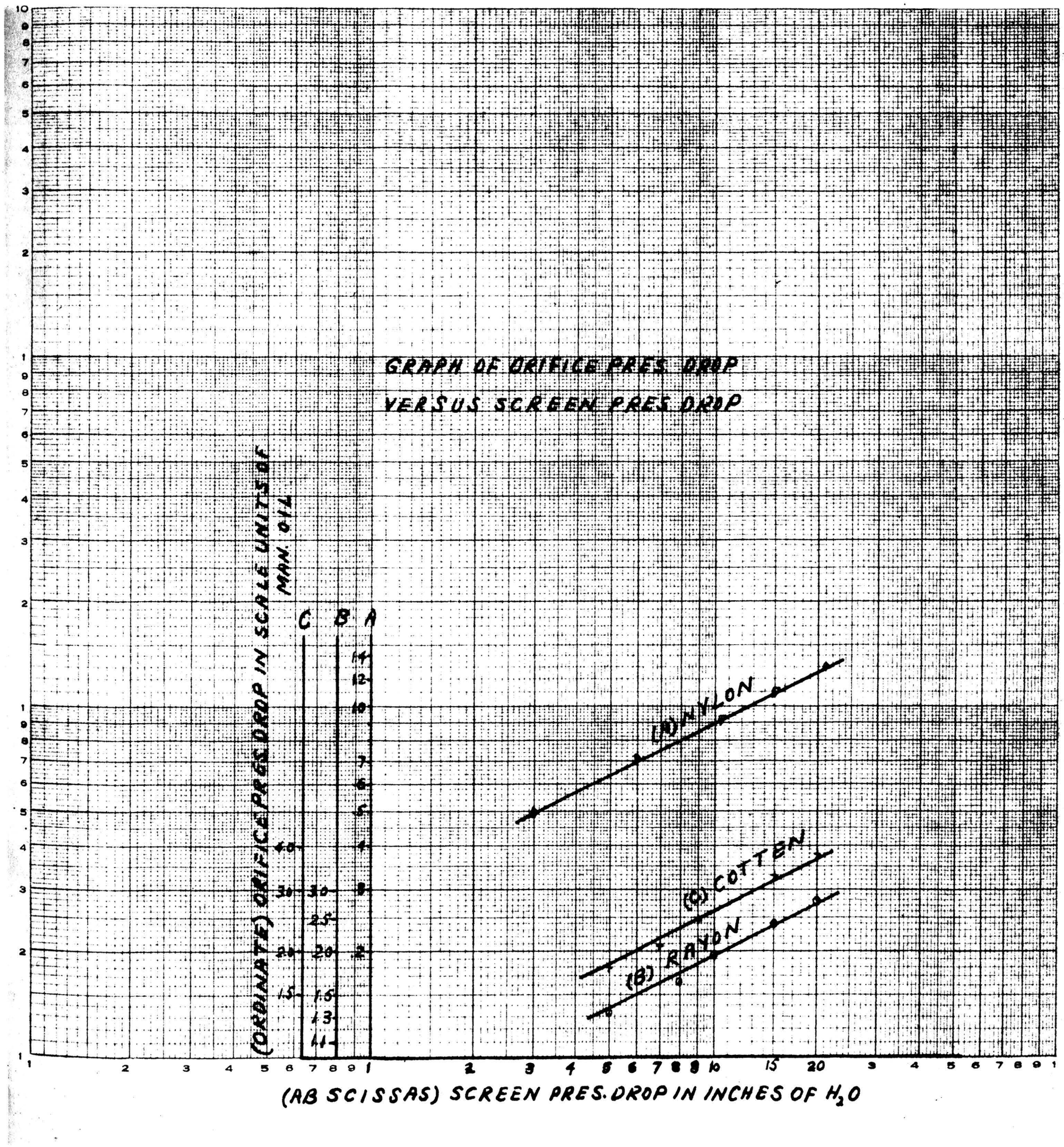
TABLE VI

Screen (C) Cotton Temp: 84°F

Run	Orifice Pressure Drop (H) in Units of Manometer Oil	$\sqrt{H}$	Screen Pressure Drop (h) Inches of Water
a	3.2	1.79	5
b	4.3	2.07	7
c	6.2	2.46	9
d	10.5	3.24	15
e	14.0	3.74	20
f	18.0	4.25	25


GRAPH OF ORIFICE PRES. DROP (H)
VERSUS SCREEN PRES. DROP (h)
C B A
(ORDINATE) ORIFICE PRES. DROP IN SCALE UNITS OF MAN. OIL
(B) RAYON
(A) NYLON
(C) COTTEN
(ABSCISSAS) SCREEN PRES. DROP IN INCHES OF H2O
0
5
10
15
20


GRAPH OF THE SQUARE ROOT OF
ORIFICE PRES DROP VERSUS
SCREEN PRES DROP
C B A
(A) NYLON
(B) RAYON
(C) COTTEN
(ORDINATE) SQUARE ROOT OF ORIFICE PRES DROP IN INCHES OF MAN OIL
(ABSCISSAS) SCREEN PRES DROP IN INCHES OF H_2O
0
5
10
15
20


GRAPH OF ORIFICE PRES. DROP
VERSUS SCREEN PRES. DROP
(ORDINATE) ORIFICE PRES. DROP IN SCALE UNITS OF MAN. OIL
C B A
(A) NYLON
(C) COTTEN
(B) RAYON
(AB SCISSAS) SCREEN PRES. DROP IN INCHES OF H_2O

DISCUSSION OF THE CURVES

It is apparent all of the three curves are parabolic in nature. A plot of the data on logarithmic coordinates verifies this assumption. If we examine these curves further, we see that they are parallel to one another which indicates that there is a definite relationship between the curves of the various screens. The dimensionally derived equation was parabolic in form, and the parallel line plots for the various screens on logarithmic coordinates indicates the air flow through all of the screens can be expressed by a single equation, if the proper values of the constants (K) and exponents (b) and (d) can be determined.

However I might make this remark about the nature of the different kinds of fabrics. Fabrics which are similar in nature like nylon and rayon have almost alike thread surface conditions. On the other hand the surface condition of cotton fabrics differ. They are very rough and fuzzy. For this reason in the determination of the constants K, b and d I shall take points on the nylon and rayon curves and leave cotton out. Then I shall introduce a factor for the surface roughness of cotton. I mean to do this by taking 3 or 4 points on the cotton curve and calculating the flow by the derived equation and plot the actual values of flow versus the values obtained from the derived equation. After obtaining a correction graph in such a manner the formula could be applied for cotton too.

DETERMINATION OF CONSTANTS

In solving for the constants, the first step is to write the dimensional equation (g) in such a form as to facilitate isolation of the exponents (b) and (d)

$$Q = K\left(\frac{\rho P}{\mu^2 M^2}\right)^b (DM)^d \left(\frac{\mu M}{\rho}\right) \qquad (g)$$

Collecting terms of like exponents

$$\frac{Q\rho}{\mu M} = K\left(\frac{\rho P}{\mu^2 M^2}\right)^b (DM)^d \qquad (h)$$

Taking the logarithims of both sides of the eq. (h)

$$\log \left(\frac{Q\rho}{\mu M}\right) = \log K + b \log \left(\frac{\rho P}{\mu^2 M^2}\right) + d \log (DM) \qquad (i)$$

Now, let us tabulate the values of the terms $\left(\frac{Q\rho}{\mu M}\right)$, $\left(\frac{\rho P}{\mu^2 M^2}\right)$, and (DM) by taking the necessary values from three different runs on nylon and rayon.

(2) J. Lipka, Graphical and Mechanical Computation, N. Y., John Wiley and Sons, 1918, p. 128

TABLE VII

Screen	Run	$\frac{(Q\rho)}{(\mu M)}$	$\frac{(\rho P)}{(\mu^2 M^2)}$	(DM)
(A) Nylon	c	117	0.675×10^6	0.788
(A) Nylon	d	141	0.975×10^6	0.788
(B) Rayon	c	321	1.065×10^6	0.646

Calculations for the Above Data Are Given Below:

$$Q = 0.0438\ CD^2 \frac{\sqrt{\rho_w \times h_w}}{\sqrt{12\rho_a}}$$

Q = Air flow (cu.ft./sec.)

C = Orifice coefficient

D = Orifice diameter (inches)

ρ_w = Density of water (lb./cu.ft.)

h_w = Orifice pressure drop (inches of water)

ρ_a = Density of air (lb./cu.ft.)

Screen (A) Nylon Run c H = 0.85

h =10.4

C = 0.65

D = 2.046 $h_w = 0.85 \times 0.0735 \times 0.834 = 0.052$" water

$$\rho_w = \frac{0.9943 \times \overline{2.54}^3 \times 1728}{453.6} = 61.5 \text{ lb./cu.ft.}$$

$$Q = 0.0438 \times 0.65 \times \overline{2.046}^2 \frac{\sqrt{61.5 \times 0.052}}{\sqrt{12 \times 0.074}}$$

$$= 0.0438 \times 0.65 \times 4.175 \times 1.9 = 0.226 \text{ cu.ft./sec.}$$

(3) N. B. Wolk, A Thesis on Air Flow Through Metallic Screenings, 1951, p. 22.

Area of Screen Sample = $\frac{\pi(1.375)^2}{144 \times 4}$ = 0.0103 sq. ft.

$Q = \frac{0.226}{0.0103} = 21.9$ ft./sec.

$\rho_a = \frac{0.074}{32.16} = 0.023$ slugs/ft.

$\mu = 0.00018 \times 0.00209 = 0.000{,}000376$ lb.sec./sq.ft.

$M = 95 \times 12 = 1140$ threads/inch

$P = \frac{10.4 \times 0.433}{12} = 54.0$ lb./ft.^{2}

Now determine $\left(\frac{Q\rho}{\mu M}\right)$, $\left(\frac{\rho P}{\mu^2 M^2}\right)$ and (DM)

$$\frac{Q\rho}{\mu M} = \frac{21.9 \times 0.0023}{0.000000376 \times 1140} = \frac{2.19 \times 2.3 \times 10^2}{3.76 \times 1.14} = 117$$

$$\frac{\rho P}{\mu^2 M^2} = \frac{0.0023 \times 54.0}{(3.76 \times 10^{-7})^2 (1140)^2} = \frac{2.3 \times 5.4 \times 10^6}{3.76^2 \times 1.14} = 0.675 \times 10^6$$

$DM = 0.0083 \times 95 = 0.788$

Screen (A) Nylon　　Run d　　　　$H = 1.2$

$h = 15$

$\rho_w = 61.5$ lb./cu.ft.

$\rho_a = 0.074$ lb./cu./ft.

$h_w = 1.2 \times 0.0735 \times 0.834 = 0.0735$ inches of water

$$Q = 0.0438 \times 0.15 \times 4.175 \frac{\sqrt{61.5 \times 0.0735}}{\sqrt{12 \times 0.074}} = 0.2571 \text{ cu.ft/sec.}$$

Area of screen = 0.0103 sq. ft.

$Q = \frac{0.2571}{0.0103} = 26.3$ ft./sec.

$\rho_a = 0.0023$ slugs/cu.ft.

$\mu = 0.000{,}000376$ lb.sec./sq.ft.

$M = 1140$ threads/inch

$P = \frac{15 \times 0.433 \times 144}{12} = 78$ lb./sq.ft.

Determination of $\frac{Q\rho}{\mu M}$, $\frac{\rho P}{\mu^2 M^2}$ and DM

$$\frac{Q\rho}{\mu M} = \frac{26.3 \times 0.0023}{0.000000376 \times 1140} = 141$$

$$\frac{\rho P}{\mu^2 M^2} = \frac{2.3 \times 7.8 \times 10^6}{\overline{3.76}^2 \times \overline{1.14}^2} = 0.975 \times 10^6$$

DM = 0.0083 x 95 = 0.788

Screen (B) Rayon   Run d   H = 5.8

h =15

ρ_w = 61.5 lb./cu.ft

ρ_a = 0.074 lb./cu.ft

h_w = 5.8 x 0.0735 x 0.834 = 0.356 inches of water

$$Q = 0.0438 \times 0.65 \times 4.175 \frac{\sqrt{61.5 \times 0.356}}{\sqrt{12 \times 0.074}} = 0.59 \text{ cu.ft./sec.}$$

Area of screen = 0.0103 sq. ft

$$Q = \frac{0.59}{0.0103} = 57.3 \text{ ft./sec.}$$

ρ_a = 0.0023 slugs/cu.ft.

μ = 0.000,000376 lb.sec./sq.ft.

M = 91 x 12 = 1092 threads/ft.

$$P = \frac{15 \times 0.433 \times 144}{12} = 78 \text{ lb./sq.ft}$$

Determination of $\frac{Q\rho}{\mu M}$, $\frac{\rho P}{\mu^2 M^2}$ and DM

$$\frac{Q\rho}{\mu M} = \frac{57.3 \times 0.0023}{0.000000376 \times 1090} = 321$$

$$\frac{\rho P}{\mu^2 M^2} = \frac{2.3 \times 7.8 \times 10^6}{\overline{3.76}^2 \times \overline{1.09}^2} = 1.065 \times 10^6$$

DM = 0.0071 x 91 = 0.646

Substituting the values for $\frac{Q\rho}{\mu M}$, $\frac{\rho P}{\mu^2 M^2}$ and DM from Table VII into eq. (i)

$$\log = \frac{Q\rho}{\mu M} = \log k + b \log \frac{\rho P}{\mu^2 M^2} + d \log DM \qquad (i)$$

$$\log 117 = \log K + b \log 0.675 \times 10^6 + d \log 0.788 \qquad (a')$$

$$\log 141 = \log K + b \log 0.975 \times 10^6 + d \log 0.788 \qquad (b')$$

$$\log 321 = \log K + b \log 1.065 \times 10^6 + d \log 0.646 \qquad (c')$$

Substituting the values of the logarithims

$$2.0682 = \log K + 5.8293b + (-0.1035)d \qquad (a')$$

$$2.1492 = \log K + 5.989\ b + (-0.1035)d \qquad (b')$$

$$2.5065 = \log K + 6.0273b + (-0.1898)d \qquad (c')$$

Rewriting eq. (a') and (b') and substracting eq. (b') from (a')

$$(5.989 - 5.8293)b = 2.1492 - 2.0682$$

$$b = \frac{0.081}{0.1597} = 0.507$$

Now substracting eq. (b') from eq. (c')

$$2.5065 - 2.1492 = (6.0273 - 5.989).507 + (-0.1898 + 0.1035)d$$

$$0.0863d = 0.01942 - 0.3573$$

$$d = -\frac{3379}{863} = -3.91$$

From eq. (b)

$$2.1492 = \log K + 5.989 \times 0.507 + 0.1035 \times 3.91$$

$$\log K = 2.1492 - 5.989 \times 0.507 - 0.1035 \times 3.91$$

$$\log K = 2.1492 - 3.04 - 0.405$$

$$\log K = -1.296$$

$$K = 0.0506$$

Eq. (i) becomes

$$Q = 0.0506 \left(\frac{\rho P}{\mu^2 M^2}\right)^{0.507} (DM)^{-3.91} \frac{(\mu M)}{(\rho)} \qquad (L)$$

CHECK FOR THE VALIDITY OF EQUATION

Example (1)

Screen (A) Nylon Run e $\quad H = 1.7$

$h = 21$

$$P = \frac{21 \times 0.433 \times 144}{12} = 109 \text{ lb./sq.ft.}$$

$$\mu = 0.000000376$$

$$\rho = \frac{0.074}{32.16} = 0.0023 \text{ slugs/cu.ft.}$$

$$Q = 0.0506 \left(\frac{2.3 \times 10.9 \times 10^6}{3.76^2 \times 1.14^2}\right)^{0.507} \left(\frac{1}{.7883 \cdot .91}\right) \left(\frac{3.76 \times .109}{2.3}\right)$$

$$= 0.0506(1.36 \times 10^6)^{.507} \left(\frac{1}{.3935}\right)(0.186)$$

$$= 0.0506 \times 1290 \times 2.54 \times .186 = 30.8 \text{ ft./sec.}$$

$$Q = 30.8 \times 0.0103 = 0.318 \text{ cu.ft./sec.}$$

$$Q = 0.0438 \; CD^2 \frac{\sqrt{\rho_w h_w}}{\sqrt{12 \rho_a}} \qquad C = 0.65$$

$$D = 2.046$$

$$\rho_w = 61.5$$

$$h_w = 1.7 \times 0.0735 \times 0.834 = 0.104 \text{ inches of water}$$

$$\rho_a = 0.074$$

$$Q = 0.0438 \times 0.65 \times 2.046^2 \frac{\sqrt{61.5 \times 0.104}}{\sqrt{12 \times 0.074}}$$

$$= 0.119 \times 2.68 = 0.292 \text{ cu.ft./sec.}$$

$$\% \text{ error} = \frac{(.318 - .292)100}{.292} = 8.9\%$$

Example (2)

Screen (B) Nylon Run e $\quad H = 7.8$

$h = 20$

$$\rho = 0.0023 \text{ slugs/cu.ft.}$$

$$P = \frac{20 \times 0.433 \times 144}{12} = 104 \text{ lb./sq.ft.}$$

$$\mu = 0.000000376 \text{ lb.sec./sq.ft.}$$

$$M = 91 \times 12 = 1090; \quad D = 0.0071 \text{ inches}$$

$$Q = 0.0506\left(\frac{2.3 \times 10.4 \times 10^6}{3.76^2 \times 1.09^2}\right)^{.507}\left(\frac{1}{.646^{3.91}}\right)\left(\frac{3.76 \times 0.109}{2.3}\right)$$

$$= 0.0506(1.545 \times 10^6)^{.507}\left(\frac{1}{.181}\right)(.178)$$

$$= 0.0506 \times 1380 \times 5.52 \times .178 = 68.6 \text{ ft./sec.}$$

$$Q = 68.6 \times 0.0103 = 0.706 \text{ cu.ft./sec.}$$

$$h_w = 7.8 \times 0.0735 \times 0.834 = 0.478 \text{ inches of water}$$

$$Q = 0.0438 \times 0.65 \times \overline{2.046^2}\frac{\sqrt{61.5 \times 0.478}}{\sqrt{12 \times 0.074}}$$

$$= 0.119 \times 5.76 = .628 \text{ cu.ft./sec.}$$

$$\% \text{ error} = \frac{(.706 - .628)}{.628} = 12.4\%$$

TABLE VIII

TABULATION OF VALUES FOR AIR FLOW AND % ERRORS

Screen	Run	Air Flow eq. (L) cu.ft./sec.	Air Flow (Actual) cu.ft./sec.	%Error
(A) Nylon	e	0.318	0.292	8.9%
(B) Rayon	e	0.706	0.628	12.4%

APPLICATION OF EQ. (L) TO COTTON BY MEANS OF THE CORRECTION GRAPH

Example(3)

$\rho = 0.0023$ $\qquad H = 4.3$

$P = \frac{7 \times 0.433 \times 144}{12} = 36.4$ lb./sq.ft. $\qquad h = 7$

$\mu = 0.000,00038$ lb.sec./sq.ft.

$M = 90 \times 12 = 1080$ $\qquad D = 0.0074$ inches

$$Q = 0.0506\left(\frac{2.3 \times 3.64 \times 10^6}{3.8^2 \times 1.08^2}\right)^{.507}\left(\frac{1}{.665^{3.91}}\right)\left(\frac{3.8 \times 0.108}{2.3}\right)$$

$$= 0.0506(.536 \times 10^6)^{.507}(4.93)(.178)$$

$$= 0.0506 \times 638 \times 4.93 \times 0.178 = 28.3 \text{ ft./sec.}$$

$$Q = 28.3 \times 0.0103 = 0.292 \text{ cu.ft./sec.}$$

$$h_w = 4.3 \times 0.0735 \times 0.834 = .263 \text{ inches of water}$$

$$Q = 0.0438 \times .65 \times \overline{2.046}^2 \frac{\sqrt{61.5 \times 0.263}}{\sqrt{12 \times 0.074}}$$

$$= .119 \times 4.26 = 0.508 \text{ cu.ft./sec.}$$

Example (4)

Screen (c) Cotton Run c $\qquad H = 6.2$

$\rho = 0.023$ $\qquad h = 9$

$P = \frac{9 \times 0.433 \times 144}{12} = 46.8$ lb./sq.ft.

$\mu = 0.000,00038$ lb.sec./sq.ft.

$D = 0.0074$ inches

$$Q = 0.0506\left(\frac{2.3 \times 4.68 \times 10^6}{3.8^2 \times 1.08^2}\right)^{.507}\left(\frac{1}{.665^{3.91}}\right)\left(\frac{3.8 \times 0.108}{2.3}\right)$$

$$= 0.0506(.69)^{.507}(4.93)(.178)$$

$$= 0.0506 \times 912 \times 4.93 \times .178 = 40.5 \text{ ft./sec.}$$

$Q = 40.5 \times 0.0103 = .417$ cu.ft./sec.

$h_w = 6.2 \times 0.0735 \times 0.834 = 0.38$

$$Q = 0.0438 \times 0.65 \times \overline{2.046^2}\frac{\sqrt{61.5 \times 0.38}}{\sqrt{12 \times 0.074}}$$

$= 0.119 \times 5.13 = 0.61$ cu.ft./sec.

Example (5)

Screen (C) Cotton Run d H = 10.5

$\rho = 0.0023$ slugs/sq.ft. h = 15

$$P = \frac{15 \times 0.433 \times 144}{12} = 78.0 \text{ lb./sq.ft.}$$

$\mu = 0.000,00038$ lb.sec./sq.ft

D = 0.0074 inches

$$Q = 0.0506\left(\frac{2.3 \times 78.0 \times 10^6}{\overline{3.8^2} \times \overline{1.08^2}}\right)^{.507}\left(\frac{1}{(.665^{3.91})}\right)\left(\frac{3.8 \times 0.108}{2.3}\right)$$

$= 0.0506(1.15)^{.507}(4.93)(.178)$

$= 0.0506 \times .1175 \times 4.93 \times .178 = 52.2$ ft./sec.

$Q = 52.2 \times 0.0103 = 0.538$ cu.ft./sec.

$h_w = 10.5 \times 0.0735 \times 0.834 = 0.643$ inches of water

$$Q = 0.0438 \times 0.65 \times \overline{2.046^2}\frac{\sqrt{61.5 \times 0.643}}{\sqrt{12 \times 0.074}}$$

$= 0.0438 \times 0.65 \times 4.175 \times 6.675 = 0.794$ cu.ft./sec.

Example (6)

Screen (C) Cotten Run e H = 14

$\rho = 0.0023$ slugs/sq.ft. h = 20

$$P = \frac{20 \times 0.433 \times 144}{12} = 104 \text{ lb./sq.ft.}$$

$\mu = 0.000,00038$ lb.sec./sq.ft.

D = 0.0074 inches

$$Q = 0.0506\frac{(23 \times 10.4 \times 10^6)^{.507}}{(3.8^2 \times 1.08^2\ \ )}\left(\frac{1}{(.665^{3.91})}\right)\left(\frac{3.8 \times 0.108}{2.3}\right)$$

$$= 0.0506(1.535)^{.507}(4.93)(.178)$$

$$= 0.0506 \times 1365 \times 4.93 \times 0.178 = 60.6 \text{ ft./sec.}$$

$$Q = 60.6 \times 0.0103 = 0.625 \text{ cu.ft./sec.}$$

$$h_w = 14 \times 0.0735 \times 0.834 = .857 \text{ inches of water}$$

$$Q = 0.0438 \times 0.65 \times \frac{2.046^2\sqrt{61.5 \times .857}}{\sqrt{12 \times 0.074}}$$

$$= 0.119 \times 7.7 = .916 \text{ cu.ft./sec.}$$

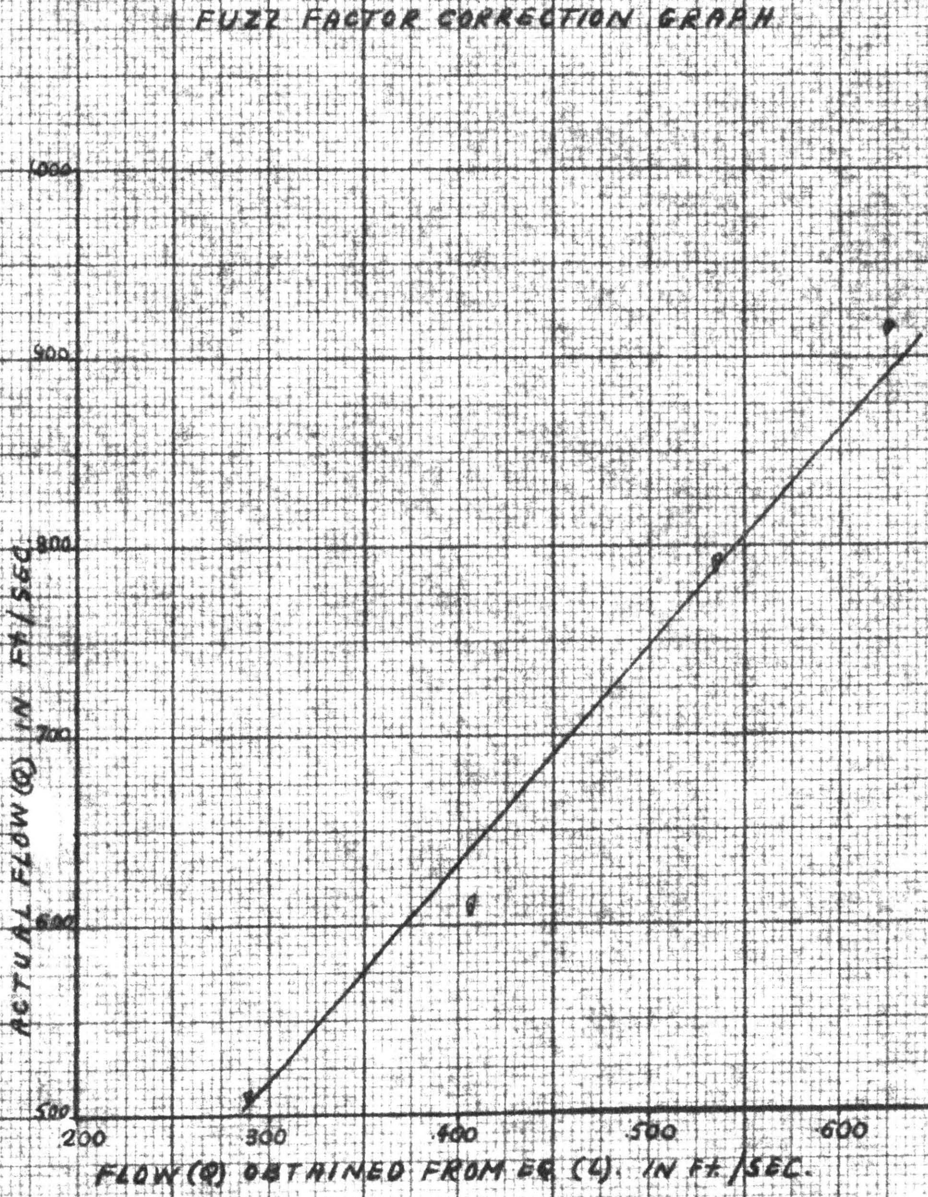
TABLE IX

Screen (C) Cotton

Run	Actual Flow (Q) in lb./cu.ft.	Flow (Q) From Derived Eq. (L) in lb./cu.ft.
b	.508	.292
c	.610	.407
d	.794	.538
e	.916	.625

Now, with the data that can be obtained from Table IX, let us draw a correction graph, that is, flow obtained from derived obtained versus the actual graph.

From observation of the graph, we can see it is a straight line function which accounts for the surface roughness of the cotton threads.


FUZZ FACTOR CORRECTION GRAPH
1000
900
800
700
600
500
ACTUAL FLOW (Q) IN Ft/SEC
200
300
400
500
600
FLOW (Q) OBTAINED FROM EQ (4). IN Ft/SEC.

CHECK FOR THE VALIDITY OF THE CORRECTION GRAPH

Example (7)

Let us take a point at random on the cotton curve.

$\rho = 0.0023$ $\qquad H = 9$

$P = \dfrac{13 \times 0.433 \times 144}{12} = 67.5$ lb./sq.ft. $\qquad h = 13$

$\mu = 0.000,00038$ lb.sec./sq.ft.

D = 0.0074 inches

$$Q = 0.0506\left(\frac{2.3 \times 6.75}{3.8^2 \times 1.08}\right)^{.507}\left(\frac{1}{.665^{3.91}}\right)\left(\frac{3.8 \times 0.108}{2.3}\right)$$

$$Q = 0.0506(0.995 \times 10^6)^{.507}(4.93)(.178)$$

$$= 0.0506 \times 1095 \times 4.93 \times 0.178 = 48.6 \text{ ft./sec.}$$

$$Q = 48.6 \times 0.0103 = 0.500 \text{ cu.ft./sec.}$$

$$h_w = 9 \times 0.0735 \times 0,834 = 0.552 \text{ inches of water}$$

$$Q = 0.0438 \times 0.65 \times 2.046^2 \frac{\sqrt{61.5 \times 0.552}}{\sqrt{12 \times 0.074}}$$

$$= 0.119 \times 6.18 = 0.736 \text{ cu.ft./sec.}$$

Now Q= 0.500 cu.ft./sec.

Q actual = 0.736 cu.ft./sec.

Using the correction graph, 0.500 cu.ft./sec. corresponds to 0.749 cu.ft./sec.

$$\% \text{ error} = \frac{(.749 - .736)100}{.736} = 1.77 \% \text{ error}$$

CONCLUSIONS

The results obtained from this investigation would seem to indicate the adaptability of the methods of dimensional analysis for solving problems of the same nature. The nature of the problem will be a major factor in the determination of the constant of proportionality and the exponential constants.

The discrepancies between the air flow as calculated from the derived equation and the measured value of the air flow by the orifice meter did not vary much, and what is more the relationship seemed to be a constant one.

This constant error may have come from a number of sources among which are the following:

(1) The readings taken on the orifice meter oil column have not been close enough. In most of the cases, especially at the beginning of the tests, little air flow was required which gave a fraction of a scale unit of manometer oil which in turn was hard to read, and consequently involved some guesswork.

(2) The pipes used in the building of the apparatus were old and contained some scale on the inside surface and as a result a streamlined flow could not have been attained.

(3) Although the thread thicknesses of the samples used seemed to be reasonably uniform to the naked eye, they proved far from being uniform under a microscope and hence an error might have been introduced there.

(4) The presence of moisture in the air might have hindered the flow of air by clogging the openings in the cloth.

(5) Although every precaution was taken in taking the readings, slight discrepancies were observed when more than one readings were made on the same sample under the same conditions, and hence an average of results were used in some instances.

As a conclusion I am willing to say with some great confidence that the equation derived is perfectly satisfactory but for one respect. Due to the condition of the surface of the threads a correction graph or a second constant (K') should be worked out for every different kind of cloth or different groups of cloth, as was derived for cotton.

By a group of cloth I mean those which have surface conditions almost similar such as nylon and rayon.

The derived formula could be applied to any kind of cloth as long as the thread surface roughness factor is obtained.

SUMMARY

The development of the general form of the equation obtained for air flow through woven materials and more specifically for woven cloth was achieved by the methods of dimensional analysis. The constant of proportionality and the exponential constants were determined by running a series of tests on the sample fabrics that were procured for that purpose.

To check the validity of the equation obtained, points were selected at random, on the curves, then the results obtained by using the derived equation were compared with the measured values. Agreements within eight to twelve % were attained in all cases.

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